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Quintessential Brane and the Cosmological Constant

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Abstract

We consider a quintessential sector realized on a hidden brane with a tiny warp factor, which implies a small value of the effective four-dimensional cosmological constant through an equation of motion for the quintessential scalar.

The minuscule scale in the physics of the cosmological constant [1, 2] or quintessence [2, 3] provides the largest hierarchy in fundamental physical parameters. This hierarchy suggests that the sector responsible for such minuscule physics may be separate from our visible sector in which the standard model of elementary particles resides.

In this paper, we pursue the possibility that this separate sector is realized on a quintessential brane which is hidden from the standard sector on another brane or in a bulk. Namely, we consider a quintessential sector realized on a hidden brane with a tiny warp factor, which implies a small value of the effective four-dimensional cosmological constant through an equation of motion for the quintessential scalar.

Let us consider a scalar field ϕ on a hidden 3-brane coupled to gravity induced from the bulk spacetime whose action is given by

$$S = \int d^4x\sqrt{-g}\left(\frac{1}{2}g^{\mu\nu}\partial_\mu\phi\partial_\nu\phi - V(\phi) + \frac{1}{2}U(\phi)R\right), \tag{1}$$

where $g_{\mu\nu}$ denotes the four-dimensional metric induced on the brane from the bulk gravity.[1]

Under a warped compactification of the higher-dimensional bulk theory, the four-dimensional metric $\bar{g}_{\mu\nu}$ visible in our world is related to the induced metric through a warp factor: $g_{\mu\nu} = a^2\bar{g}_{\mu\nu}$ [4, 5, 6]. Then the sector given by Eq.(1) amounts to

$$S = \int d^4x\sqrt{-\bar{g}}\left(\frac{1}{2}\bar{g}^{\mu\nu}\partial_\mu\bar{\phi}\partial_\nu\bar{\phi} - \bar{V}(\bar{\phi}) + \frac{1}{2}\bar{U}(\bar{\phi})\bar{R}\right) \tag{2}$$

in the effective four-dimensional theory, where $\bar{\phi} = a\phi$, $\bar{V}(\bar{\phi}) = a^4V(\phi)$ and $\bar{U}(\bar{\phi}) = a^2U(\phi)$. Note that $\bar{V}(\bar{\phi})$ and $\bar{U}(\bar{\phi})$ do not directly yield the vacuum energy and the gravitational constant in our universe: there are contributions (of larger size) from the standard sector and others on another brane or in a bulk, which are not explicit here.

When the warp factor a^2 is tiny,[2] the potential $\bar{V}$ can be quintessentially small without fine tuning provided the potential V in terms of the fundamental metric $g_{\mu\nu}$ is smaller than the fundamental scale. In fact, the equation of motion for the constant scalar field

[1]The potential $V(\phi)$ may be flat due to (super)symmetry at a large scale in terms of the fundamental metric $g_{\mu\nu}$.

[2]The warp factor can be exponentially small [5] with an AdS slice in an S^1/Z_2 orbifold [5, 6], for instance. Such a concrete example with its interpretation as spacetime inflation will be given elsewhere.

is given by

$$\frac{1}{2}\bar{U}'\bar{R} = \bar{V}', \tag{3}$$

that is,

$$\frac{1}{2}U'\bar{R} = a^2 V', \tag{4}$$

which may realize the quintessential vanishing of the four-dimensional cosmological constant [7] with V'/U' not too large. We note that this is possible since the four-dimensional metric induced on the brane from the bulk spacetime has meanings independent of the field-dependent Weyl rescalings on the brane in the warped compactification.

References

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